ISL71090SEH

Total Dose Testing

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Introduction and Executive Summary

This report discusses the results of total dose testing of four versions of the ISL71090SEH precision voltage reference. These tests were conducted to provide an assessment of the total dose hardness of the parts and their dose rate and bias sensitivity; tests of three of the four variants added a biased high temperature anneal to look at the part's accelerated aging response. Samples were irradiated under bias and with all pins grounded at low dose rate and at high dose rate. Some samples were annealed at 100°C under bias for 168 hours as well (see Table 1).

The ISL71090SEH variants are acceptance tested on a wafer-by-wafer basis to 100krad(Si) at high dose rate (50rad(Si)/s) to 300rad(Si)/s) and to 50krad(Si) at low dose rate (0.01rad(Si)/s), insuring hardness to the specified level for both dose rates.

The variants of the ISL71090SEH reported on include the ISL71090SEHVF12 (1.25V nominal output voltage), ISL71090SEHVF25 (2.5V nominal output voltage), ISL71090SEHVF50 (5.0V nominal output voltage) and ISL71090SEHVF75 (7.5V nominal output voltage). These variants use the same base die, with the output voltage selected by trimming to obtain the desired output voltage. The package contains only the silicon die and there are no separate internal or external passive components (i.e., resistors or capacitors) used to set the output voltage. As these tests were carried out during the development phase some had small sample sizes and we will discuss this issue later in this report.

The ISL71090SEH showed good performance over low and high dose rate irradiation. All samples passed the post-irradiation specifications at the total dose levels specified in the SMD. We observed dose rate sensitivity and bias sensitivity in the critical output voltage parameter (see "Discussion and Conclusion" on page 16) and the part is considered moderately low dose rate sensitive. All other parameters were stable. We also saw interesting biased high temperature anneal responses in the output voltage and these responses will be discussed as well.

Related Literature

- MIL-STD-883 test method 1019
- ISL71090SEH12, ISL71090SEH25, ISL71090SEH50, ISL71090SEH75 datasheets
- Standard Microcircuit Drawing (SMD) 5962-13211

Features

- DLA SMD# 5962-13211
- Initial accuracy . . . . ±0.05%
- Output voltage noise . . . . 1.9µV_{P-P} typical . . . . (0.1Hz to 10Hz) (2.5V option)
- Supply current . . . . 1.28mA maximum
- Tempco . . . . 10ppm/°C maximum
- Output current capability, sourcing . . . . 20mA maximum
- Output current capability, sinking . . . . 10mA maximum
- Line regulation . . . . 18ppm/V maximum
- Load regulation . . . . 35ppm/mA maximum, sourcing
- Load regulation . . . . 70ppm/mA maximum, sinking
- Operating temperature range. . . . . -55°C to +125°C
- Radiation environment
  - High dose rate . . . . 100krad(Si)
  - Low dose rate . . . . 50krad(Si)
  - SET/SEL/SEB . . . . 86MeV•cm^2/mg

Part Description

The ISL71090SEH is a low noise precision voltage reference with a wide input voltage range from 4.0V to 30V, with four output voltage options selected through on-chip trimming. The ISL71090SEH is built on the Intersil PR40 bonded-wafer process, which uses dielectric isolation for important electrical and SEE performance improvements. The part achieves sub 2µV peak-to-peak 0.1Hz noise with an initial voltage accuracy of 0.05%. The ISL71090SEH offers four output voltage options including 1.25V, 2.5V, 5.0V and 7.5V and features a 10ppm/°C temperature coefficient and excellent line and load regulation. The device is offered in an 8 Ld hermetic flatpack. Applications include instrumentation, data acquisition systems, and strain and pressure sensing for space applications. Key features and specifications follow.

Test Description

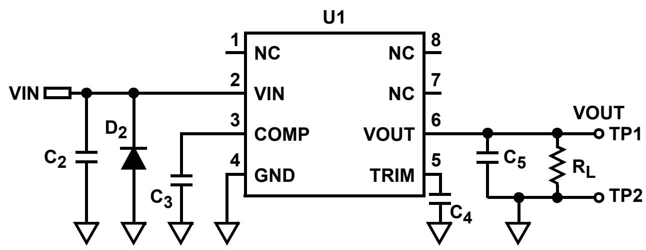
Irradiation Facilities

High dose rate testing was performed at an average dose rate of 67.87rad(Si)/s using a Gammacell 220 ^{60}Co irradiator located in the Palm Bay, Florida Intersil facility. Low dose rate testing was performed at 0.01rad(Si)/s using the Intersil Palm Bay N40 panoramic low dose rate ^{60}Co irradiator. Post-irradiation high temperature biased anneals were performed using a small temperature chamber.

Test Fixturing

Figure 1 shows the configuration used for biased irradiation. The grounded irradiations were performed in the same fixture type with all pins hardwired to ground.

Post-irradiation high temperature biased anneals were performed using this configuration as well.



PARTS:
V_{IN} = +36V ±10%
R_1 = 3.86k, 1%, 1W
R_2 = 470, 1%, 1W
R_L = 5k, 1%, 1/4W
C_2 = 0.1µF, 50V, 10%, X7R
C_3, C_4 = 0.01µF, 50V, 10%, X7R
C_5 = 0.1µF, 10V, 10%, X7R

FIGURE 1. BIASED IRRADIATION CONFIGURATION FOR THE ISL71090SEH

Characterization Equipment and Procedures

All electrical testing was performed outside the irradiator using the production Automated Test Equipment (ATE) with datalogging at each downpoint. All downpoint electrical testing was performed at room temperature. Control units were used to verify repeatability.

Experimental Matrix

The experimental matrix is shown in Table 1. Samples of four variants of the ISL71090SEH were drawn from preproduction PR40 lot WWH4AE and were packaged in hermetic 8 Ld ceramic flatpacks (package code KCJ). Samples were processed through the standard burn-in cycle before irradiation, as required by MIL-STD-883, and were screened to the ATE limits at room temperature prior to the test.

A biased 168-hour post-irradiation high temperature anneal at 100°C was performed on all samples after irradiation. The 7.5V variant samples were annealed following the *low* dose rate irradiations only. All anneal results are included in Figures 2 through 24.

Downpoints

Downpoints and pass/fail statistics are shown in the attributes data table (Table 1).

Results

Attributes Data

Table 1 shows the test attributes data.

TABLE 1. ISL71090SEH TOTAL DOSE TEST ATTRIBUTES DATA

PART	DOSE RATE (RAD(Si))	BIAS	SAMPLE SIZE	DOWNPOINT	PASS (Note 1)	FAIL
ISL71090SEHVF12	0.01	Figure 1	5	Pre-irradiation	5	
				30krad(Si)	5	0
				50krad(Si)	5	0
				100krad(Si)	4	1
				150krad(Si)	0	5
				Anneal	0	5
ISL71090SEHVF12	0.01	Grounded	5	Pre-irradiation	5	
				30krad(Si)	5	0
				50krad(Si)	5	0
				100krad(Si)	5	0
				150krad(Si)	4	1
				Anneal	1	4
ISL71090SEHVF12	67.8	Figure 1	5	Pre-irradiation	5	
				30krad(Si)	5	0
				50krad(Si)	5	0
				100krad(Si)	5	0
				150krad(Si)	5	0
				Anneal	5	0

TABLE 1. ISL71090SEH TOTAL DOSE TEST ATTRIBUTES DATA (Continued)

PART	DOSE RATE (RAD(Si))	BIAS	SAMPLE SIZE	DOWNPOINT	PASS (Note 1)	FAIL
ISL71090SEHVF12	67.8	Grounded	5	Pre-irradiation	5	
				30krad(Si)	5	0
				50krad(Si)	5	0
				100krad(Si)	5	0
				150krad(Si)	5	0
				Anneal	5	0
ISL71090SEHVF25	0.01	Figure 1	5	Pre-irradiation	5	
				30krad(Si)	5	0
				50krad(Si)	4	1
				75krad(Si)	2	3
				100krad(Si)	0	5
				150krad(Si)	0	5
				Anneal	1	4
ISL71090SEHVF25	0.01	Grounded	5	Pre-irradiation	5	0
				25krad(Si)	5	0
				30krad(Si)	5	0
				50krad(Si)	5	0
				100krad(Si)	5	0
				150krad(Si)	5	0
				Anneal	3	0
ISL71090SEHVF25	67.8	Figure 1	7	Pre-irradiation	7	
				30krad(Si)	7	0
				50krad(Si)	7	0
				100krad(Si)	7	0
				150krad(Si)	7	0
				Anneal	7	0
ISL71090SEHVF25	67.8	Grounded	7	Pre-irradiation	7	
				30krad(Si)	7	0
				50krad(Si)	7	0
				100krad(Si)	7	0
				150krad(Si)	7	0
				Anneal	7	0
ISL71090SEHVF50	67.8	Figure 1	5	Pre-irradiation	5	
				30krad(Si)	5	0
				50krad(Si)	5	0
				100krad(Si)	5	0
				150krad(Si)	5	0
				Anneal	5	0

TABLE 1. ISL71090SEH TOTAL DOSE TEST ATTRIBUTES DATA (Continued)

PART	DOSE RATE (RAD(Si))	BIAS	SAMPLE SIZE	DOWNPOINT	PASS (Note 1)	FAIL
ISL71090SEHVF50	67.8	Grounded	5	Pre-irradiation	5	
				30krad(Si)	5	0
				50krad(Si)	5	0
				100krad(Si)	5	0
				150krad(Si)	5	0
				Anneal	5	0
ISL71090SEHVF50	0.01	Figure 1	2	Pre-irradiation	2	
				50krad(Si)	2	0
				100krad(Si)	0	2
				150krad(Si)	0	2
				Anneal	1	1
ISL71090SEHVF50	0.01	Grounded	2	Pre-irradiation	2	
				50krad(Si)	2	0
				100krad(Si)	2	0
				150krad(Si)	2	0
				Anneal	1	1
ISL71090SEHVF75	67.8	Figure 1	4	Pre-irradiation	4	
				100krad(Si)	4	0
ISL71090SEHVF75	67.8	Grounded	3	Pre-irradiation	3	
				100krad(Si)	3	0
ISL71090SEHVF75	0.01	Figure 1	2	Pre-irradiation	2	
				25krad(Si)	2	0
				50krad(Si)	2	0
				100krad(Si)	0	2
				150krad(Si)	0	2
				Anneal	2	0
ISL71090SEHVF75	0.01	Grounded	2	Pre-irradiation	2	
				25krad(Si)	2	0
				50krad(Si)	2	0
				100krad(Si)	2	0
				150krad(Si)	1	1
				Anneal	2	0

NOTE:

1. 'Pass' indicates a sample that passes all post-irradiation SMD limits.

Variables Data

The plots in Figures 2 through 24 show data at all downpoints. Figures 2 through 6 report the response of the ISL71090SEHVF12 samples; Figures 7 through 12 report the results for the ISL71090SEHVF25 samples; Figures 13 through 18 report the results for the ISL71090SEHVF50 and Figures 19 through 24 report the results for the ISL71090SEHVF75. The plots report the response of all four variants to total dose irradiation at low and high dose rates for the biased (per Figure 1) and unbiased (all pins grounded) cases. We chose to plot the median for these parameters due to the relatively small sample sizes and show the minimum and maximum values for each datapoint as well. "Discussion and Conclusion" on page 16 will provide individual discussion of the figures.

Data Plots

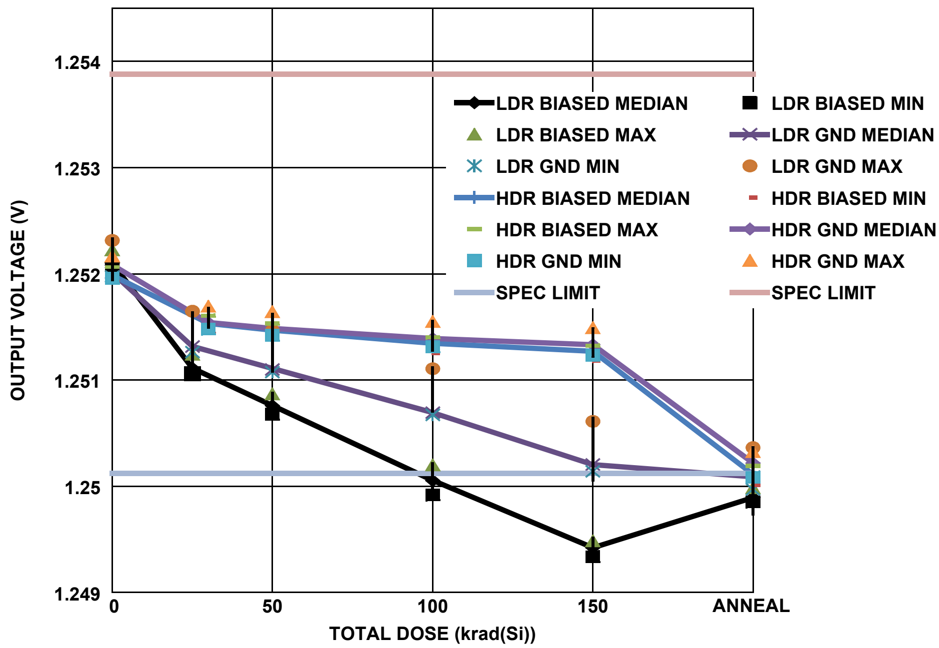


FIGURE 2. ISL71090SEHVF12 output voltage as a function of total dose irradiation at low and high dose rate for the biased (per Figure 1) and unbiased (all pins grounded) cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 5 at high dose rate under bias, 5 at high dose rate with all pins grounded, 5 samples at low dose rate under bias and 5 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limits are 1.250122V to 1.253878V.

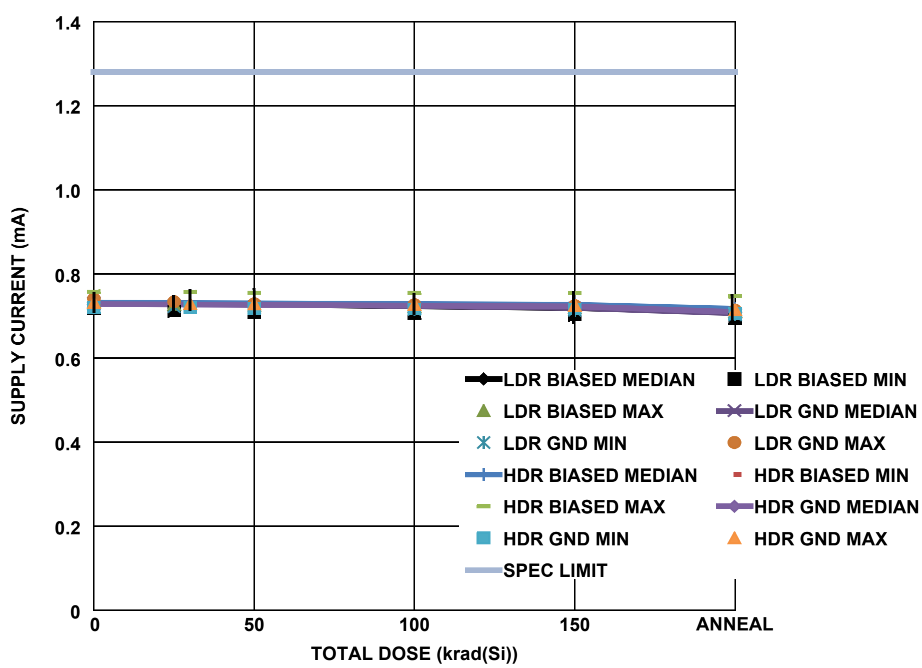


FIGURE 3. ISL71090SEHVF12 power supply current as a function of total dose irradiation at low and high dose rate for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 5 at high dose rate under bias, 5 at high dose rate with all pins grounded, 5 samples at low dose rate under bias and 5 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is 1.28mA maximum.

Data Plots (Continued)

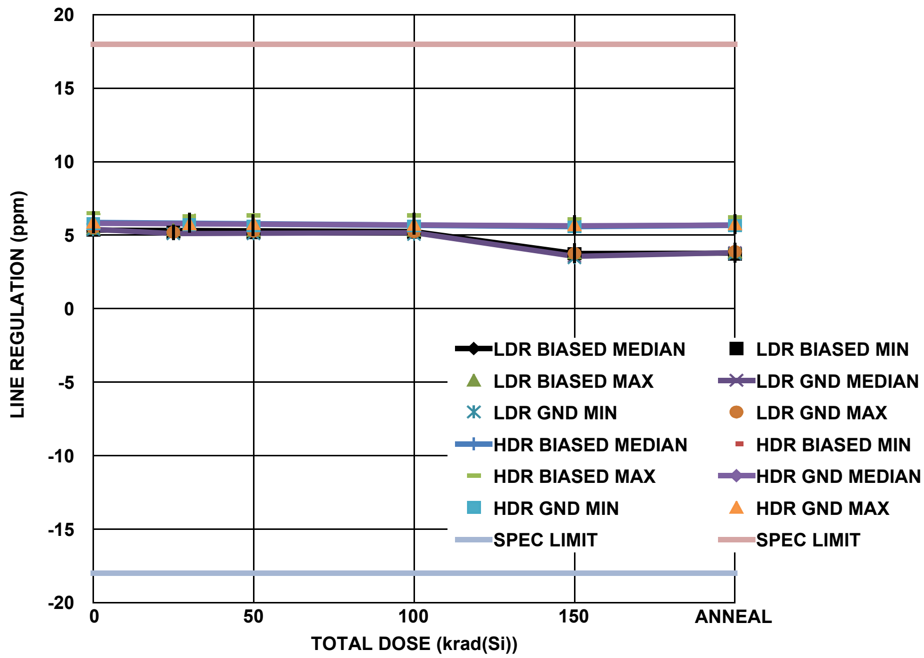


FIGURE 4. ISL71090SEHVF12 line regulation as a function of total dose irradiation at low and high dose rate for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 5 at high dose rate under bias, 5 at high dose rate with all pins grounded, 5 samples at low dose rate under bias and 5 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is 18.0ppm/V maximum.

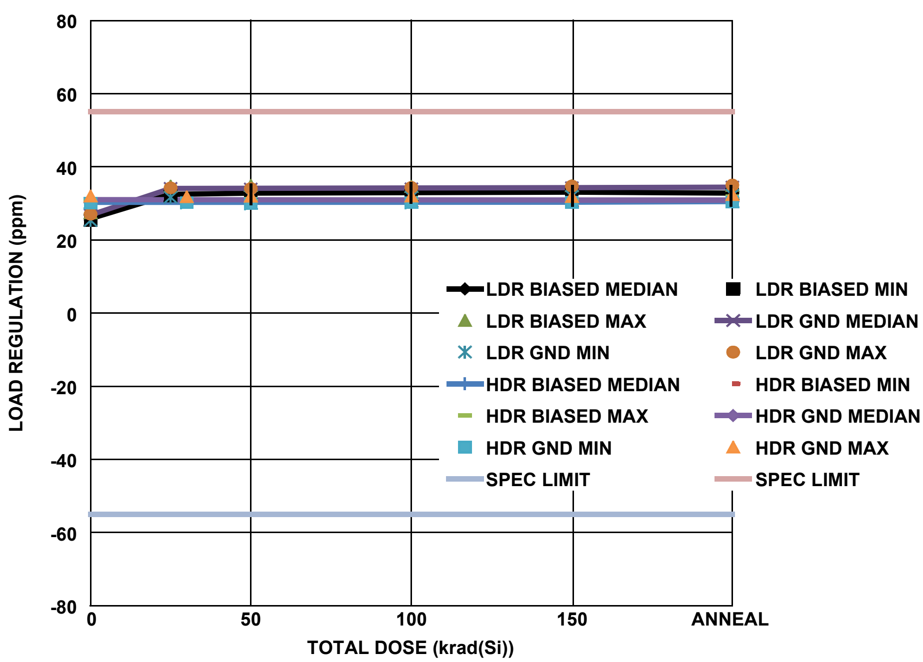


FIGURE 5. ISL71090SEHVF12 load regulation, +20mA sourcing, as a function of total dose irradiation at low and high dose rate for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 5 at high dose rate under bias, 5 at high dose rate with all pins grounded, 5 samples at low dose rate under bias and 5 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is 55.0ppm/mA maximum.

Data Plots (Continued)

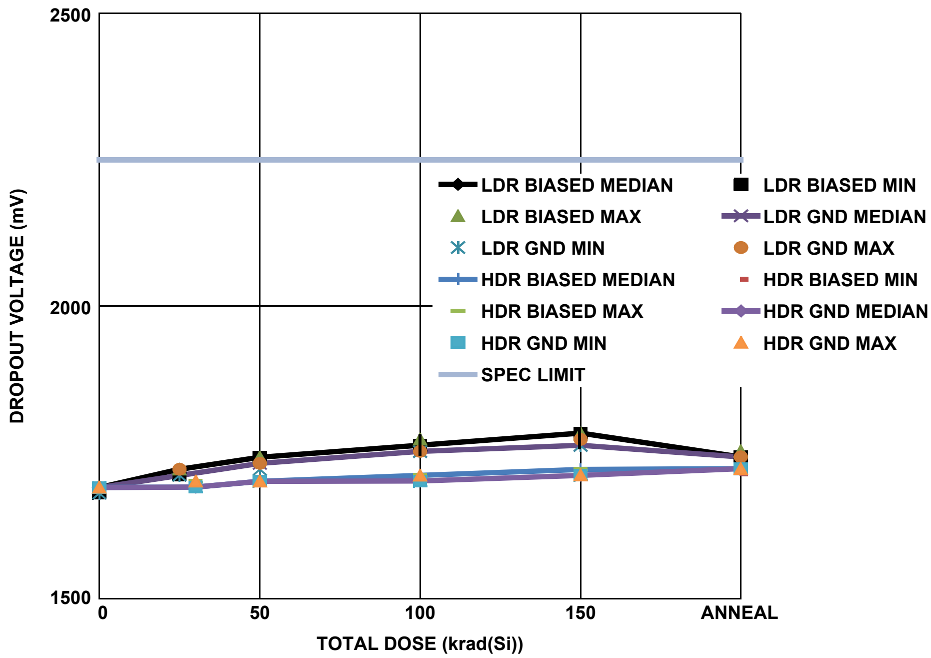


FIGURE 6. ISL71090SEHVF12 dropout voltage as a function of total dose irradiation at low and high dose rate for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 5 at high dose rate under bias, 5 at high dose rate with all pins grounded, 5 samples at low dose rate under bias and 5 samples at low dose rate with all pins grounded. The post-irradiation specification limit is 2250mV maximum.

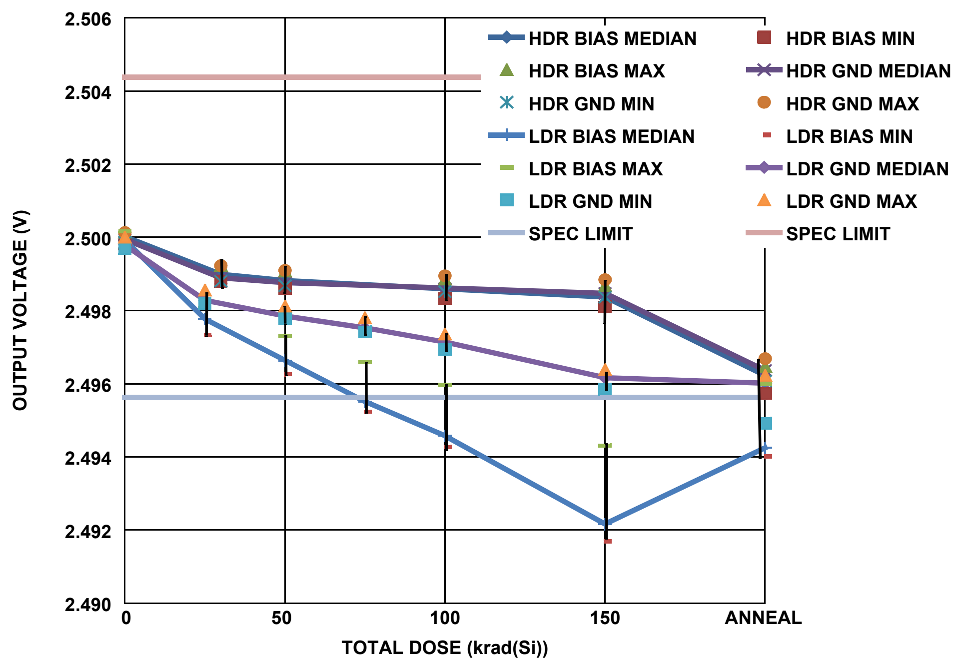


FIGURE 7. ISL71090SEHVF25 output voltage as a function of total dose irradiation at low and high dose rate for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 7 at high dose rate under bias, 7 at high dose rate with all pins grounded, 5 samples at low dose rate under bias and 5 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limits are 2.495625V to 2.504375V.

Data Plots (Continued)

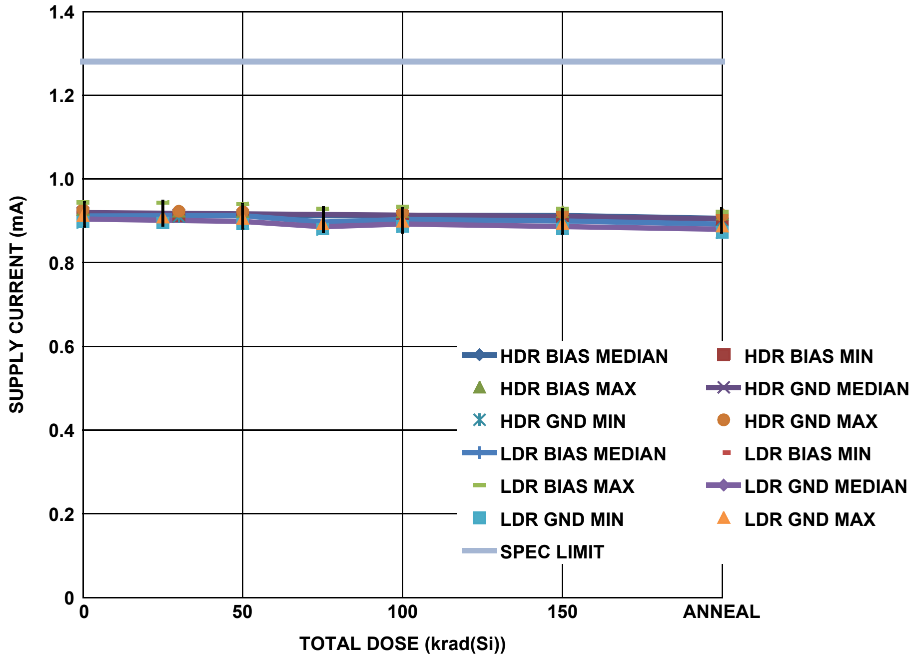


FIGURE 8. ISL71090SEHVF25 power supply current as a function of total dose irradiation at low and high dose rate for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 7 at high dose rate under bias, 7 at high dose rate with all pins grounded, 5 samples at low dose rate under bias and 5 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is 1.28mA maximum.

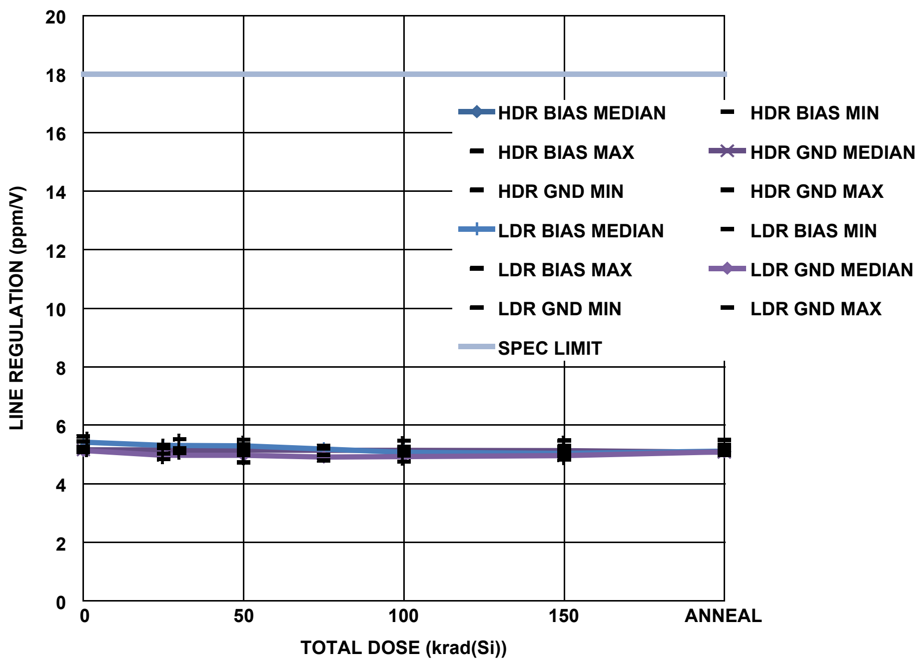


FIGURE 9. ISL71090SEHVF25 line regulation as a function of total dose irradiation at low and high dose rate for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 7 at high dose rate under bias, 7 at high dose rate with all pins grounded, 5 samples at low dose rate under bias and 5 samples at low dose rate with all pins grounded. The post-irradiation specification limit is 18.0ppm/V maximum.

Data Plots (Continued)

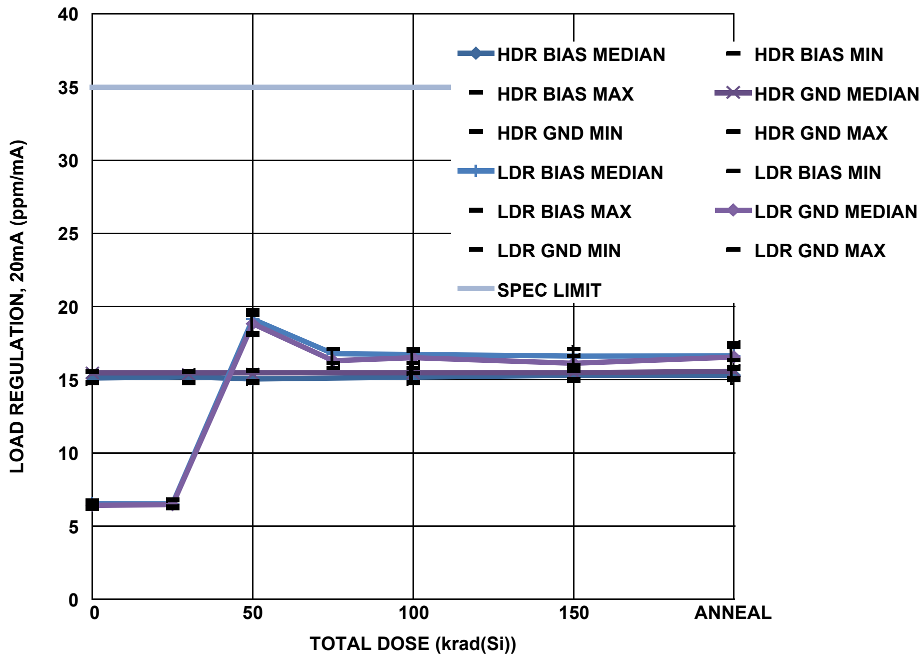


FIGURE 10. ISL71090SEHVF25 load regulation, +20mA sourcing, as a function of total dose irradiation at low and high dose rate for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 7 at high dose rate under bias, 7 at high dose rate with all pins grounded, 5 samples at low dose rate under bias and 5 samples at low dose rate with all pins grounded. The post-irradiation specification limit is 35.0ppm/mA maximum.

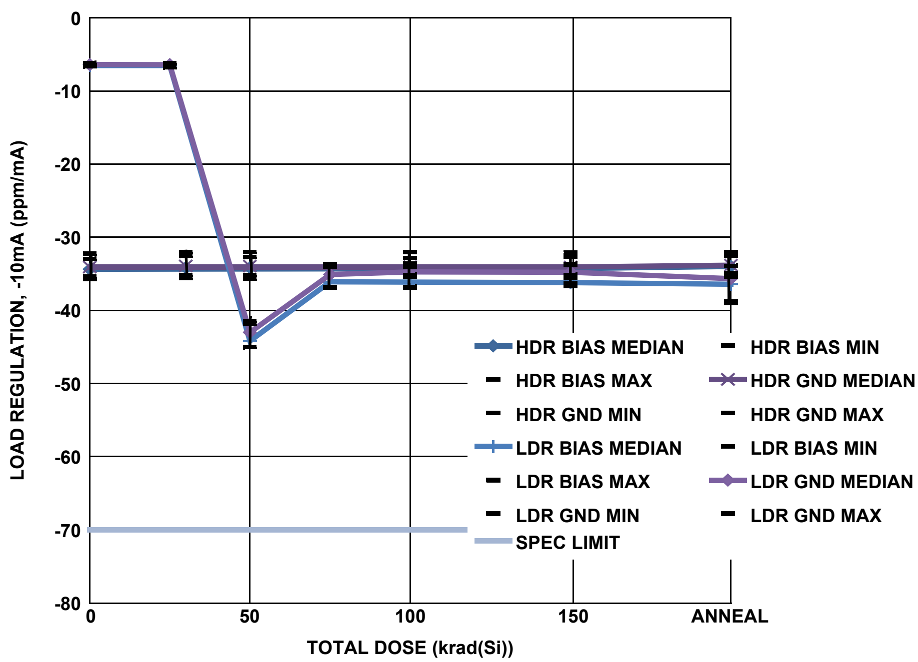


FIGURE 11. ISL71090SEHVF25 load regulation, -10mA sinking, as a function of total dose irradiation at low and high dose rate for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 7 at high dose rate under bias, 7 at high dose rate with all pins grounded, 5 samples at low dose rate under bias and 5 samples at low dose rate with all pins grounded. The post-irradiation specification limit is -70.0ppm/mA maximum.

Data Plots (Continued)

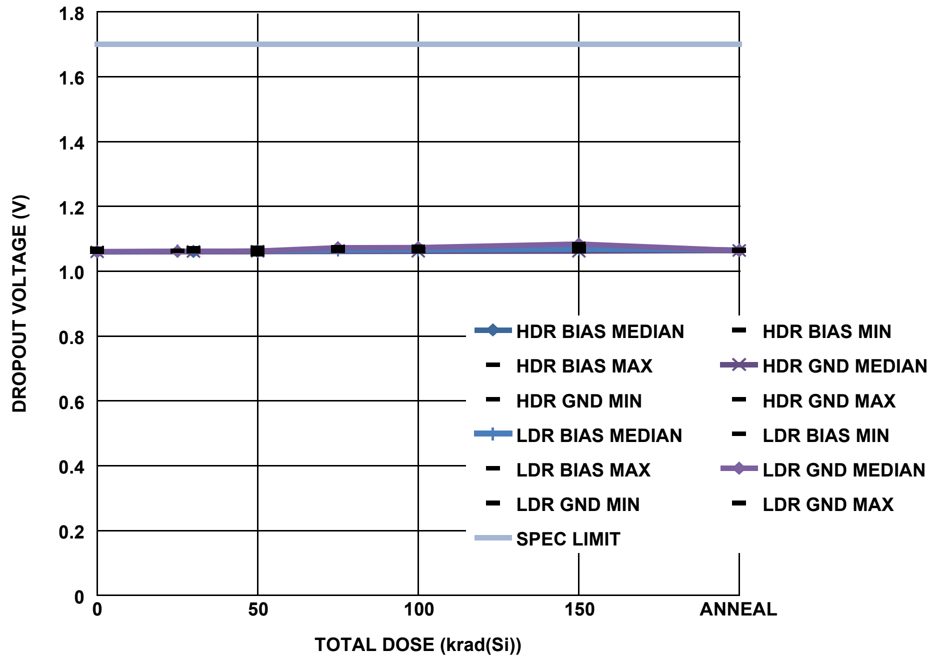


FIGURE 12. ISL71090SEHVF25 dropout voltage as a function of low and high dose rate total dose irradiation for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 7 at high dose rate under bias, 7 at high dose rate with all pins grounded, 5 samples at low dose rate under bias and 5 samples at low dose rate with all pins grounded. The post-irradiation specification limit is 1.7V maximum.

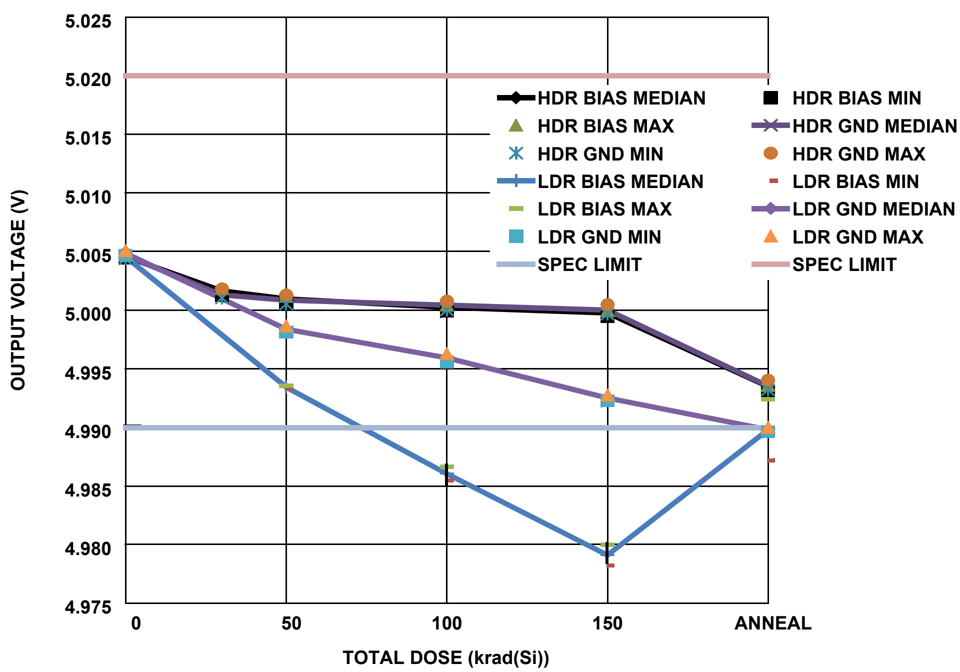


FIGURE 13. ISL71090SEHVF50 output voltage as a function of high dose rate total dose irradiation for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 5 at high dose rate under bias, 5 at high dose rate with all pins grounded, 2 samples at low dose rate under bias and 2 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limits are 4.989985V to 5.020015V.

Data Plots (Continued)

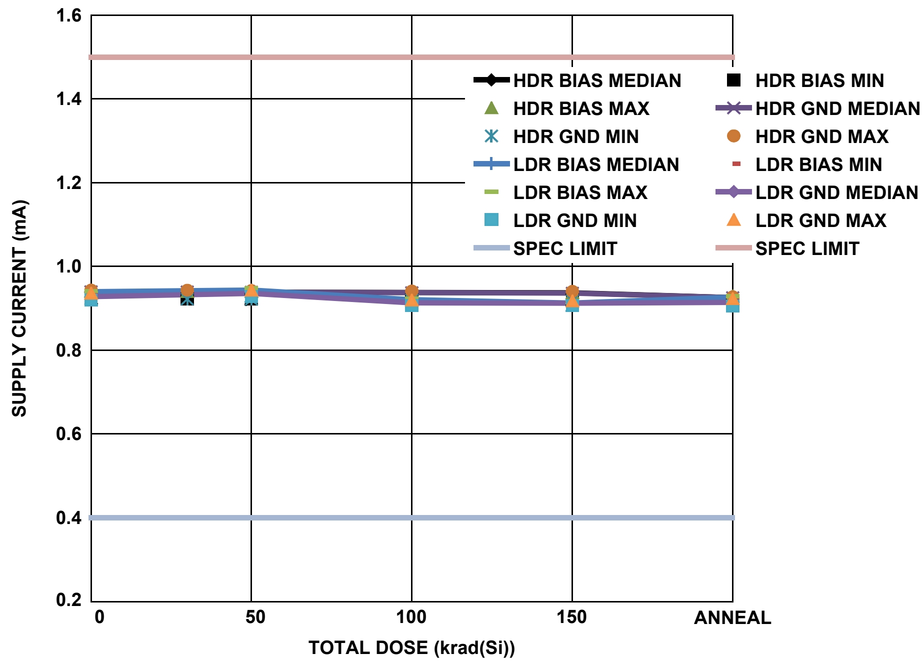


FIGURE 14. ISL71090SEHVF50 supply current as a function of high dose rate total dose irradiation for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 5 at high dose rate under bias, 5 at high dose rate with all pins grounded, 2 samples at low dose rate under bias and 2 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is 1.5mA maximum; the 0.4mA bound is an ATE limit.

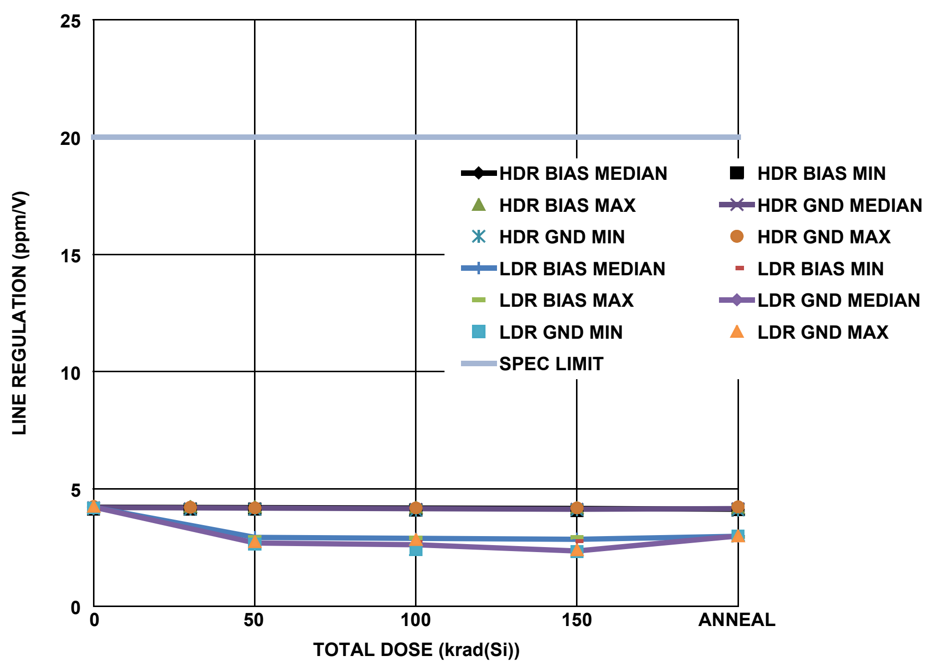


FIGURE 15. ISL71090SEHVF50 line regulation as a function of high dose rate total dose irradiation for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 5 at high dose rate under bias, 5 at high dose rate with all pins grounded, 2 samples at low dose rate under bias and 2 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is 20ppm/V maximum.

Data Plots (Continued)

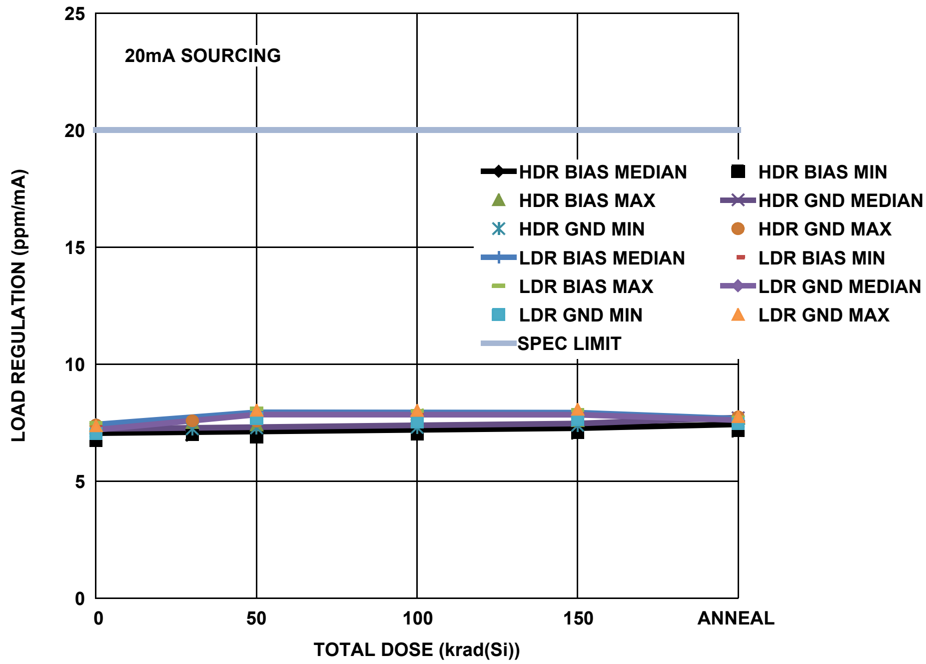


FIGURE 16. ISL71090SEHVF50 load regulation, +20.0mA sourcing, as a function of high dose rate total dose irradiation for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 5 at high dose rate under bias, 5 at high dose rate with all pins grounded, 2 samples at low dose rate under bias and 2 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is 20.0ppm/mA maximum.

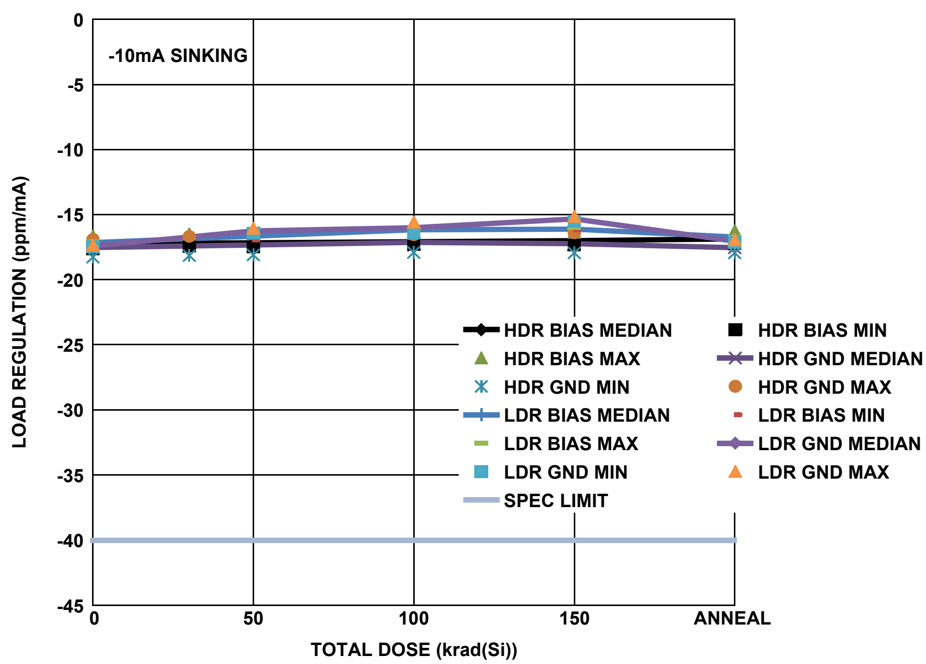


FIGURE 17. ISL71090SEHVF50 load regulation, -10mA sinking, as a function of high dose rate total dose irradiation for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 5 at high dose rate under bias, 5 at high dose rate with all pins grounded, 2 samples at low dose rate under bias and 2 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is -40ppm/mA maximum.

Data Plots (Continued)

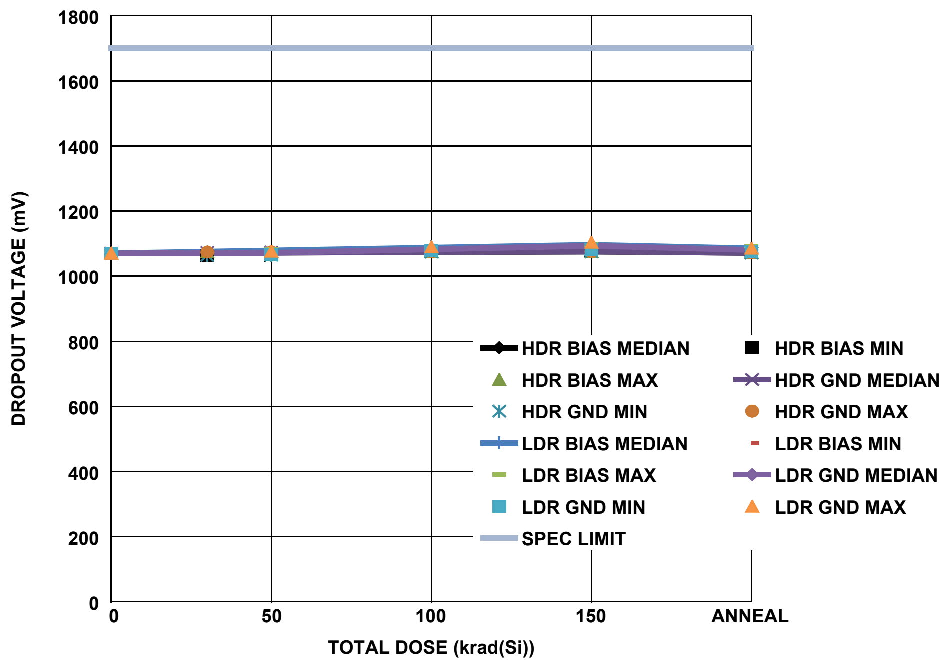


FIGURE 18. ISL71090SEHVF50 dropout voltage as a function of high dose rate total dose irradiation for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation. The irradiations were followed by a biased anneal at 100°C for 168 hours. Sample sizes were 5 at high dose rate under bias, 5 at high dose rate with all pins grounded, 2 samples at low dose rate under bias and 2 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is 1700mV maximum.

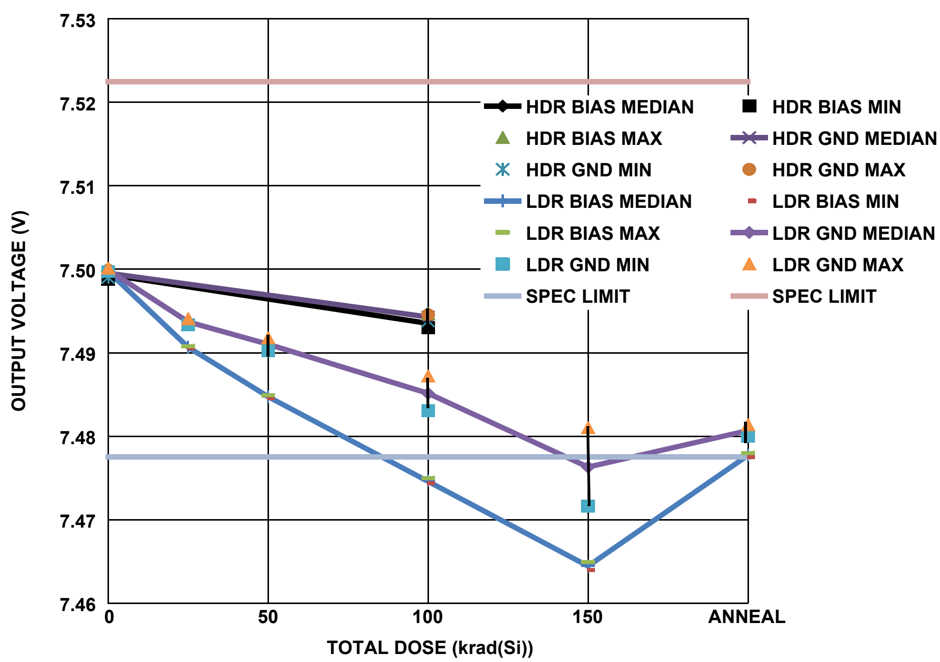


FIGURE 19. ISL71090SEHVF75 output voltage as a function of high dose rate total dose irradiation for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation, and no anneal was performed. Sample sizes were 4 at high dose rate under bias, 3 at high dose rate with all pins grounded, 2 samples at low dose rate under bias and 2 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limits are 7.477500V to 7.522500V.

Data Plots (Continued)

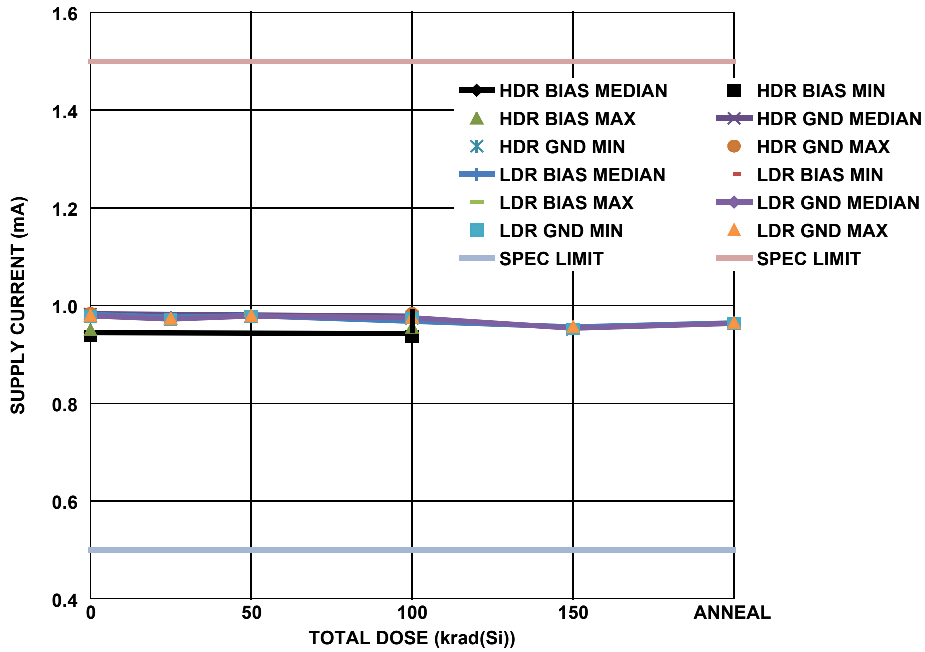


FIGURE 20. ISL71090SEHVF75 supply current as a function of high dose rate total dose irradiation for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation, and no anneal was performed. Sample sizes were 4 at high dose rate under bias, 3 at high dose rate with all pins grounded, 2 samples at low dose rate under bias and 2 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is 1.5mA maximum; the 0.5mA bound is an ATE limit.

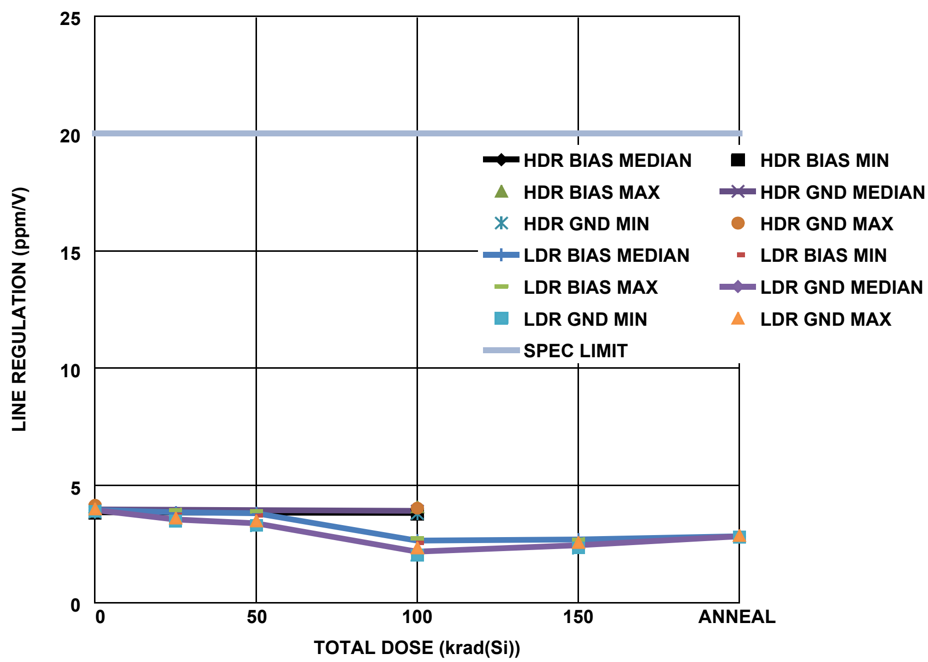


FIGURE 21. ISL71090SEHVF75 line regulation as a function of high dose rate total dose irradiation for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation, and no anneal was performed. Sample sizes were 4 at high dose rate under bias, 3 at high dose rate with all pins grounded, 2 samples at low dose rate under bias and 2 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is 20ppm/V maximum.

Data Plots (Continued)

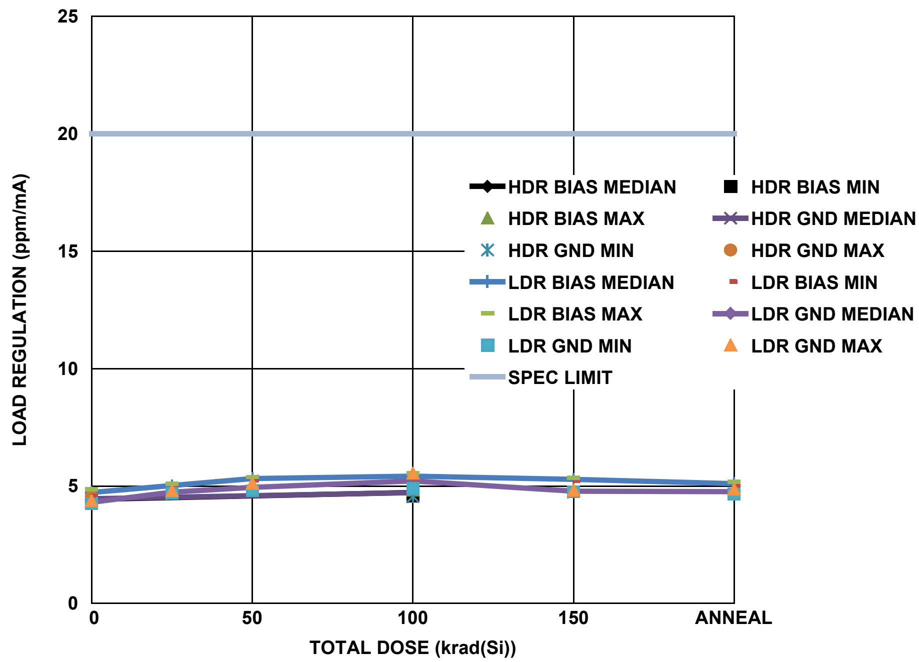


FIGURE 22. ISL71090SEHVF75 load regulation, +20mA sourcing, as a function of high dose rate total dose irradiation for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation, and no anneal was performed. Sample sizes were 4 at high dose rate under bias, 3 at high dose rate with all pins grounded, 2 samples at low dose rate under bias and 2 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is 20ppm/mA maximum.

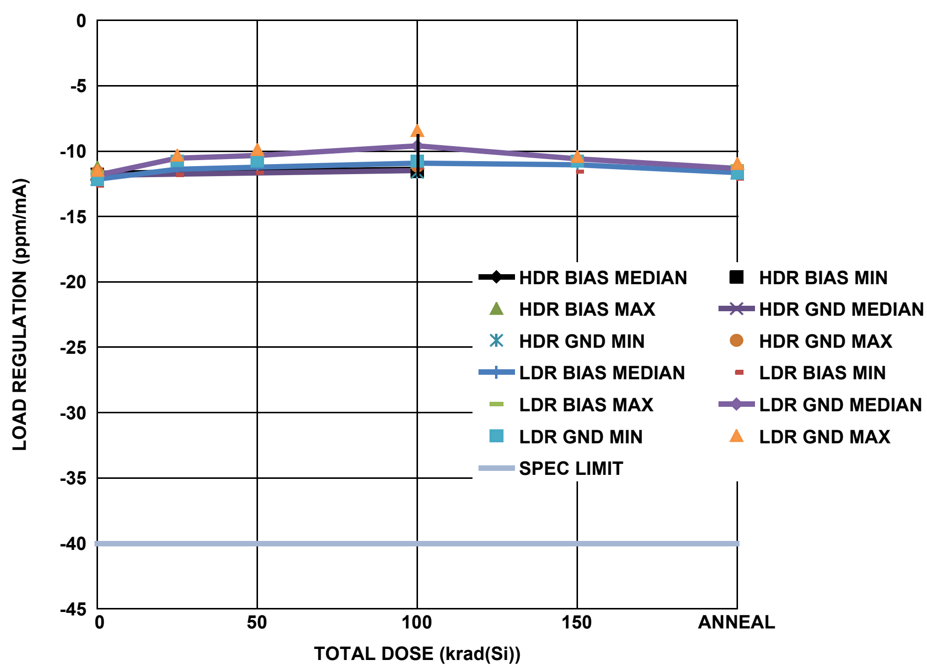


FIGURE 23. ISL71090SEHVF75 load regulation, -10mA sinking, as a function of high dose rate total dose irradiation for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation, and no anneal was performed. Sample sizes were 4 at high dose rate under bias, 3 at high dose rate with all pins grounded, 2 samples at low dose rate under bias and 2 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is -40ppm/mA maximum.

Data Plots (Continued)

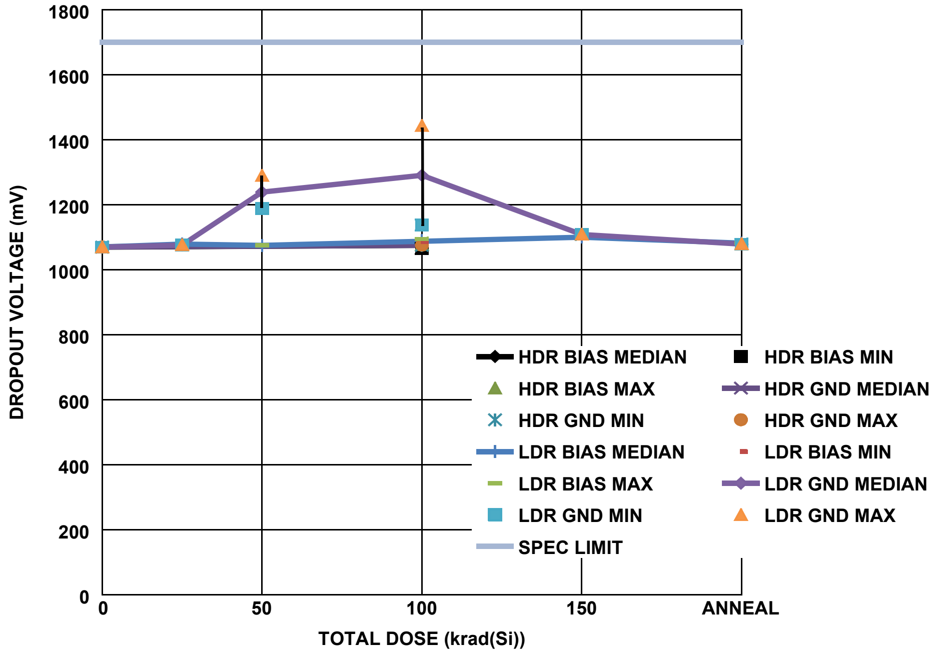


FIGURE 24. ISL71090SEHVF75 dropout voltage as a function of high dose rate total dose irradiation for the biased and unbiased cases. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 68rad(Si)/s for high dose rate irradiation, and no anneal was performed. Sample sizes were 4 at high dose rate under bias, 3 at high dose rate with all pins grounded, 2 samples at low dose rate under bias and 2 samples at low dose rate with all pins grounded. The SMD post-irradiation specification limit is 1700mV maximum.

Discussion and Conclusion

This document reports the results of low and high dose rate testing of four variants of the ISL71090SEH voltage reference. Samples were irradiated under bias and with all pins grounded at low and high dose rate in (approximate, see later sample size discussion) accordance with the MIL-STD-883 Test Method 1019 dose rate sensitivity protocol, at 0.01rad(Si)/s and 68rad(Si)/s, respectively. All irradiations were followed by a biased anneal at 100°C for 168 hours. The sample sizes and downpoints for each test are given in Table 1 on page 2. This is a simple part, at least functionally, and we have summarized the results in Table 1 (followed by curves of interest (Figures 2 through 24). We will discuss each of the figures separately, grouped by parameter. Many of the tests had very limited sample sizes, making the statistics somewhat difficult. This is not a desirable situation but reflects the lack of sample parts during development. Note also that the four variants are based on the same die and the results are expected to correlate closely; see Figures 2, 7, 13 and 19, which plot the output voltage and which are closely similar. The other parameters showed little variation over irradiation.

The output voltage is clearly the key parameter for a precision voltage reference. The 1.25V and 2.5V variants (Figure 2 and 7) showed change as a function of high and low dose rate irradiation but remained within the SMD limits after 150krad(Si) at high dose rate and 50krad(Si) at low dose rate; these are the total dose levels specified in the Intersil datasheet and the SMD. The 5.0V variant (Figure 13) showed moderate change after 150krad(Si) at high dose rate, biased and grounded, but was outside the SMD limits after 100krad(Si) and 150krad(Si) at low dose rate; it remained within the SMD limits after 50krad(Si), which is the low dose rate specification for the part. Similarly, the 7.5V variant (Figure 19) showed change after 100krad(Si) at high dose rate, biased and grounded, however, was outside the SMD limits after 100krad(Si) and 150krad(Si) at low dose rate; it remained well within the SMD limits after 50krad(Si), which again, is the low dose rate specification for the part. All variants of the ISL71090SEH should be considered moderately low dose rate sensitive.

In all cases biased irradiation at low dose rate was worst case, and by a considerable margin. This of course does not line up well with the conventional wisdom that grounded low dose rate irradiation is worst case for all-bipolar devices, which the ISL71090SEH variants are; the PR40 process does not support MOS devices. This is not however, surprising, as the behavior has been observed before on PR40 parts and points out the absolute necessity of avoiding assumptions in total dose testing. The ISL71090SEH variants are acceptance tested on a wafer-by-wafer basis to 100krad(Si) at high dose rate (50rad(Si)/s) to 300rad(Si)/s) and to 50krad(Si) at low dose rate (0.01rad(Si)/s), biased and unbiased, insuring hardness to the specified level for both dose rates.

The responses of the output voltage to the 168-hour biased anneals at +100°C were interesting. The 1.25V variant (Figure 2) showed recovery towards the pre-irradiation value for the post-low dose rate anneals, but a further degradation away from the pre-irradiation value for the post-high dose rate anneals, with the anneal signature strongest for the biased low dose rate irradiation. The 2.5V variant (Figure 7) showed a closely similar response, as did the 5.0V variant (Figure 13) and the 7.5V variant

(Figure 19), although the 7.5V variant was irradiated to only 100krad(Si) at high dose rate and was not annealed after that irradiation. There is no reason to believe the 7.5V part would respond differently.

As in the low dose rate results, these annealing responses also disagree with conventional total dose testing wisdom. First, post-irradiation annealing has been assumed to have an effect in CMOS devices only, and the ISL71090SEH is an all-bipolar design. Also, anneals are assumed to lead to recovery (and in some cases 'rebound') of the affected parameter rather than further degradation. Finally, anneals following low dose rate irradiation are assumed to be unnecessary as they will not produce any parametric change. As stated above, these unconventional responses have been observed in PR40 designs before [1], however, a detailed understanding of the physics would require a great deal of testing, with anneals after intermediate downpoints, not always practical in a production environment.

Figures 3, 8, 14 and 20 show the total dose response of the power supply current for each of the variants. The parameter was very stable at all downpoints and showed no dose rate sensitivity, bias sensitivity or annealing response. The parameter remained well within the SMD post-irradiation limits at all downpoints.

Figures 4, 9, 15 and 21 show the total dose response of the line regulation for each of the variants. The parameter was also stable at all downpoints and showed no dose rate sensitivity, bias sensitivity or annealing response. The parameter remained well within the SMD post-irradiation limits at all downpoints.

Figures 5, 10, 16 and 22 show the total dose response of the load regulation, with the part sourcing 20mA, for each of the variants. The parameter was stable and remained well within the SMD post-irradiation limits at all downpoints and showed no dose rate sensitivity or bias sensitivity. Referring to Figures 5 and 10, note that the low dose rate data was stable at the 25krad(Si) downpoint but then showed an abrupt change while still remaining well within the specification limits. The cause of this change is not known, but is believed to be artifactual. The 5.0V (Figure 10) and 7.5V variants did not show this behavior.

Figures 11, 17 and 23 show the total dose response of the load regulation, in this case with the part sinking 10mA, for the 2.5V, 5.0V and 7.5V variants; the parameter is not specified for the 1.25V variant. As in the 20mA sourcing load regulation case the parameter was stable and remained well within the SMD post-irradiation limits at all downpoints and showed no dose rate sensitivity or bias sensitivity. We did observe possibly artifactual changes in the low dose rate data for the 2.5V variant, see above comments.

Finally Figures 6, 12, 18 and 24 show the total dose response of the dropout voltage. We observed some minor variations but the parameter was stable at all downpoints and showed no dose rate sensitivity, bias sensitivity or annealing response for any of the four variants. The parameter remained well within the SMD post-irradiation limits. Figure 24 shows the response of the 7.5V variant; the grounded low dose rate case shows an increase of this parameter after 50krad(Si) and a further increase after 100krad(Si) followed by recovery after 150krad(Si). Given the very limited sample size this is likely artifactual, and at any rate the parameter stayed well within the SMD limits.

To summarize, all four variants of the ISL71090SEH showed good performance over low and high dose rate irradiation. All samples passed the post-irradiation after the specified levels of 100krad(Si) at high dose rate (50rad(Si)/s to 300rad(Si)/s) and of 50krad(Si) at low dose rate (0.01rad(Si)/s). The output voltage data showed a substantial difference between the high and low dose rate responses for all four variants, and the ISL71090SEH should be considered moderately low dose rate sensitive. Rejects were encountered after biased low dose rate irradiation to 100krad(Si) and 150krad(Si), which represents a 2x overtest with respect to the rated 50krad(Si). The part is acceptance tested on a wafer by wafer basis to the rated levels, insuring hardness to the specified level at both dose rates. This change in the output voltage is believed to be caused by radiation-induced change in the bandgap voltage, which is the basic reference network for the part.

The output voltage data also showed biased irradiation to be worst case, which represents a change from conventional radiation testing wisdom but has been seen before for this process. No measurable differences in the total dose response were noted between biased and grounded irradiation for the other parameters. The post-irradiation high temperature biased anneals produced some interesting responses; further testing would be required to assess the effects of anneals carried out after irradiation to the SMD level, rather than after substantial overtest levels as in this work.

Appendices

Reported Parameters and their Post-Irradiation Limits

FIGURE	PARAMETER	VARIANT (V)	LIMIT (LOW)	LIMIT (HIGH)	UNITS	NOTES
2	Output Voltage	1.25	1.250122	1.253878	V	
3	Power Supply Current	1.25	-	1.28	mA	
4	Line Regulation	1.25	-	18.0	ppm/V	
5	Load Regulation, Sourcing	1.25	-	55.0	ppm/mA	+20.0mA
6	Dropout Voltage	1.25	-	2250	mV	
7	Output Voltage	2.5	2.495625	2.504375	V	
8	Power Supply Current	2.5	-	1.28	mA	
9	Line Regulation	2.5	-	18.0	ppm/V	
10	Load Regulation, Sourcing	2.5	-	35.0	ppm/mA	+20.0mA
11	Load Regulation, Sinking	2.5	-	-70.0	ppm/mA	-10.0mA
12	Dropout Voltage	2.5	-	1.7	V	
13	Output Voltage	5.0	4.989985V	5.020015V	V	
14	Power Supply Current	5.0	-	1.5	mA	
15	Line Regulation	5.0	-	20.0	ppm/V	
16	Load Regulation, Sourcing	5.0	-	20.0	ppm/mA	+20.0mA
17	Load Regulation, Sinking	5.0	-	-40.0	ppm/mA	-10.0mA
18	Dropout Voltage	5.0	-	1700	mV	
19	Output Voltage	7.5	7.477500V	7.522500V	V	
20	Power Supply Current	7.5	-	1.5	mA	
21	Line Regulation	7.5	-	20.0	ppm/V	
22	Load Regulation, Sourcing	7.5	-	20.0	ppm/mA	+20.0mA
23	Load Regulation, Sinking	7.5	-	-40.0	ppm/mA	-10.0mA
24	Dropout Voltage	7.5	-	1700	mV	

References

[1] N. W. van Vonno, S. D. Turner, E. J. Thomson, B. Williams, S. J. Schulte, L. G. Gough and J. E. Shick, 'Radiation Testing Results for the Intersil ISL71590SEH Temperature Sensor', 2013 IEEE Radiation Effects Data Workshop Record, pp. 129 – 132 (2013).

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